APPLICATION UNDER UNITED STATES PATENT LAWS

Invention: **AUTOMATIC QUALITY OF SERVICE ASSIGNMENT IN ETHERNET SWITCHES**

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This is a:

[ ] Provisional Application

[X] Regular Utility Application

[ ] Continuing Application

[ ] PCT National Phase Application

[ ] Design Application

[ ] Reissue Application

[ ] Plant Application

SPECIFICATION

AUTOMATIC QUALITY OF SERVICE ASSIGNMENT IN ETHERNET SWITCHES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates generally to Ethernet devices. More particularly, it relates to an efficient and cost effective manner of automatically assigning a quality of service to an Ethernet packet.

2. Background

Ethernet is a widely-installed local area network (LAN) technology. Using an Ethernet interface, many computer devices can communicate with one another over a LAN. Ethernet is specified in a well known standard, IEEE 802.3.

An Ethernet LAN typically uses twisted pair wires or coaxial cable. The most commonly installed Ethernet systems are called 10Base-T and provide transmission speeds up to 10 megabits per second (MBPS). Fast Ethernet, or 100Base-T, provides transmission speeds up to 100 Mbps.

Ethernet devices can transmit packets using a wide range of packet sizes, e.g. from 60 bytes up to 1514 bytes. Ethernet uses a wide range of packet sizes because it is intended for data streams.

Recently there has been growing interest in converging additional types of traffic, e.g., voice stream traffic on a single infrastructure such as an Ethernet network. Converging voice and data traffic allows for lower costs while optimizing network utilization.

However, data streams and voice streams have different characteristics. Data streams tend to use large packets which are transmitted at relatively high, variable data rates, e.g., greater than 400

bytes and 100-400 kbps. Data streams also tend to transmit data packets in "bursts" at random times.

Unlike data streams, voice streams tend to use "short" packets which are transmitted at a relatively low constant bit rate, e.g., less than 400 bytes and less than 100 kbps.

In order to provide telephony (i.e. voice) services that approximate traditional telephones over a network, voice streams containing voice information must be handled differently than data streams.

Fig. 6 shows conceptually how a conventional Ethernet device may handle a voice stream and data stream at the same time. A conventional Ethernet device **600** provides a high priority queue **604** and a low priority queue **605**. Packets in the high priority queue **604** are processed preferentially over packets in the low priority queue **605**.

Input stream **610** includes a low priority data packet **603** which arrives first at Ethernet device **600**, a voice stream comprised of voice packets **601a** and **601b**, and a high priority data packet **602**. Voice packets **601a** and **601b** and high priority data packet **602** are directed to the high priority queue **604**. Low priority data packet **603** is directed to the low priority queue **605**.

Output stream **611** illustrates how the Ethernet device **600** preferentially processes packets in the high priority data queue **604**. Although low priority data packet **603** arrived first, the low priority data packet **603** is transmitted last in the output stream as output packet **609**. Voice packets **601a** and **601b** and high priority data packet **602** are transmitted preferentially as output packets **607a**, **608**, and **607b** respectively.

Conventional Ethernet devices generally direct packets to a particular priority queue by evaluating their MAC addresses, by using the 802.1 protocol, or by inspecting the contents of the Ethernet packet and

evaluating the higher-level protocols contained inside. In particular, the IEEE has extended the Ethernet protocol via 802.1p to add a field that explicitly assigns packets to priority queues.

Fig. 7 shows a more detailed view of a typical Ethernet device which provides multiple priority queues.

In particular, as shown in Fig. 7, a conventional Ethernet device **500** includes an input queue **501**, an input controller **502** with an explicit configuration **504**, a series of output queues **503** to **503n**, an output controller **505**, and a transmit queue **506**.

The input queue **501** receives incoming data packets and buffers them until they are evaluated by the input controller **502**.

The input controller **502** interrogates packets buffered in the input queue **501** and evaluates their contents (i.e. MAC address). The input controller **502** typically uses explicit configuration **504** to decide which output queue (i.e. output queues **503** to **503n**) to forward the packet.

Output queues **503-503n** allow a packet to be buffered until it is serviced by the output controller **505**. The output controller **505** prepares the packet for transmission and forwards the packet to the transmit queue **506**.

Packets in the transmit queue **506** are then transmitted to the Ethernet LAN **507**.

Unfortunately, conventional Ethernet devices require a complex explicit configuration to provide multiple priorities. Explicit configurations require trained personnel to design the settings and to enter them into the conventional Ethernet device.

The Ethernet network could perhaps implement the 802.1p priority mechanism. However, for the 802.1p mechanism to work properly, all end points in the network must include software that is 802.1p-aware, which is capable of accessing the 802.1p mechanism in

the network, and all Ethernet switches in the network must be 802.1p compliant for the packets to propagate correctly through the network.

Maintaining a staff of trained personnel is difficult for small or medium sized organizations which often do not even have a full-time network manager.

Furthermore, an explicit configuration must continually be updated by a trained person whenever a change occurs in the Ethernet LAN. Thus, conventional Ethernet devices which require explicit configurations are difficult to maintain and prone to errors.

Accordingly, there is a need for a technique and device which provides the quality of service available in an explicitly-managed device, without requiring trained personnel to manually configure and maintain the Ethernet device.

SUMMARY OF THE INVENTION

In accordance with the principles of the present invention, an automatic, adaptive voice/data device, comprises a high priority transmission queue; a low priority transmission queue. A data rate detector detects a data rate of a data stream from a particular source. A periodicity detector detects a periodicity between data packets from the particular source. The data packets are provided to the high priority transmission queue and the low priority transmission queue based on their data rate and periodicity.

In accordance with another aspect of the present invention, a method of automatically assigning a quality of service in an automatic, adaptive voice/data device, comprises identifying a data flow from a particular source. A data rate of the data flow is determined. A periodicity of a receipt of packets in the data flow is determined. A particular Quality of Service is assigned based on the data rate and periodicity.

In accordance with another aspect of the present invention, a method of optimizing a quality of service in an automatic, adaptive voice/data device, comprises identifying a high priority packet in a data flow based solely on a history of packets received from a same source. An expected next arrival time of a next high priority packet in the data flow is calculated. It is determined whether a pending low priority packet interferes with a transmission of the next high priority packet in the data flow. The high priority packet is forwarded in the data flow.

BRIEF DESCRIPTION OF THE DRAWINGS

Features and advantages of the present invention will become apparent to those skilled in the art from the following description with reference to the drawings, in which:

Fig. 1 shows an exemplary topology for providing voice services over an Ethernet network, in accordance with the principles of the present invention.

Fig. 2 shows an automatic, adaptive voice/data Ethernet device including a quality of service ("QoS") allowing for automatic quality of service assignment, in accordance with the principles of the present invention.

Fig. 3 is a detailed exemplary drawing of a QoS table, in accordance with the principles of the present invention.

Fig. 4 shows how automatic quality of service assignment is performed at the input side of an automatic, adaptive voice/data Ethernet device, in accordance with the principles of the present invention.

Fig. 5 shows how automatic quality of service optimization is performed at the output side of an automatic, adaptive voice/data Ethernet device, in accordance with the principles of the present invention.

Fig. 6 shows a conventional Ethernet device which uses an explicit configuration to handle simultaneous data streams, voice streams and multiple priority queues.

Fig. 7 shows a conventional Ethernet device including a plurality of output queues with multiple priorities.

DETAILED DESCRIPTION OF ILLUSTRATIVE EMBODIMENTS

The present invention allows automatic quality of service assignment in an automatic, adaptive voice/data Ethernet device in order to provide voice telephony services. Moreover, priority queuing is accomplished in a way that does not require the entire network to be 802.1p compliant.

Fig. 1 shows an exemplary topology for providing automatic, adaptive voice services using Ethernet devices.

In particular, one or more voice device(s) **704** (e.g., a telephone) may be coupled to an automatic, adaptive voice/data Ethernet device **701** in accordance with the principles of the present invention. One or more data device(s) **706** such as a personal computer may be coupled to automatic, adaptive voice/data Ethernet device **701**.

The automatic, adaptive voice/data Ethernet device **701** is connected via network **703** to a complementary automatic, adaptive voice/data Ethernet device **702**. Network **703** is a conventional network (e.g., the Internet) which can support both voice and data traffic.

One or more second voice device(s) **705** may be connected to the complementary automatic, adaptive voice/data Ethernet device **702**. One or more data device(s) **707** may also be connected to automatic, adaptive voice/data Ethernet device Ethernet device **702**.

In a manner similar to the way conventional Ethernet devices "learn" media access control ("MAC") addresses, automatic, adaptive voice/data Ethernet devices **701** and **702** learn which incoming

data streams are likely to be voice streams, and assigns high priority to such presumed data streams without requiring explicit user management to configure the device.

Streams from voice devices **704** and **705** will be relatively constant bit rate with fixed-size packets arriving at the automatic, adaptive voice/data Ethernet devices **701** and **702** with constant source addresses and constant destination addresses. Voice streams can be distinguished from data streams (such as those originating from data devices **706** and **707**) automatically and adaptively by the automatic, adaptive voice/data Ethernet devices **701** and **702** and assigned an appropriate quality of service. Thus, streams from voice devices **704** and **705** via the automatic, adaptive voice/data Ethernet devices **701** and **702** can approximate traditional voice telephony without requiring user management.

Fig. 2 shows a more detailed depiction of an exemplary embodiment of an automatic, adaptive voice/data Ethernet device 701 and **702** which can provide voice telephony services without requiring explicit user management.

In particular, as shown in Fig. 2, automatic, adaptive voice/data Ethernet device **701** includes an input queue **102**, an input controller **103**, a data period detector **109**, a data rate detector **110**, output queues **105** and **105n**, an output controller **107**, a transmit queue **108**, a QoS table **104**, and a clock **106**.

The input queue **102** buffers packets as they arrive at the Ethernet device **701**. While in the input queue **102**, the packets are interrogated by the input controller **103**.

The input controller **103** interrogates packets in the input queue **102** to determine if it is part of a particular stream (e.g. a voice stream). For example, the input controller **103** may identify a voice stream by constancy of it's source address and destination address of a packet.

The input controller **103** then refers to the data period detector **109**, data rate detector **110** and QoS table **104** to determine if a packet is part of a voice stream or data stream based on rate and periodicity and forwards the packet to the appropriate output queue **105** and **105n**. The data period detector **109** detects a consistency of periodicity between data packets from a particular source (e.g. voice device **704** and **705**). Upon detecting a consistency of periodicity, the data period detector **103** creates and/or modifies an entry in the QoS table **104.** Preferably, the data period detector **103** detects a consistency of periodicity by continually calculating the data period between the time stamps of data packets with a constant source address. However, any method of detecting a relatively constant periodicity from a particular source is within the principles of the present invention.

The data rate detector **110** determines the data rate of data streams identified by the data period detector **109** as having a consistency of periodicity. The data rate detector **110** then creates and/or modifies an entry in the QoS table **104**. Preferably, the data rate detector calculates data rate by dividing the packet size of a particular packet by the data period detected by the data period detector **109**.

Output queues **105** and **105n** and the output controller **107** operate in conjunction to provide multiple priorities within the Ethernet device **701**. For example, output queue **105** may correspond to "high" priority traffic (e.g. voice packets in a voice stream) while output queue **105n** may correspond to "low" priority traffic (e.g. data packets in a data stream for a file transfer). Multiple levels of priority in addition to "high" and "low" are within the principles of the present invention.

The output controller **107** decides which output queue to forward the packet in order to maintain a particularly desired quality of service.

The output controller **107** may service the output queues **105** and **105n** by a wide variety of algorithms known by those skilled in the art. Preferably, the output controller **107** treats a voice stream as constant bit rate quality of service which is preferentially serviced over most other types of traffic. However, the principles of the present invention apply to any type of multiple priority queuing algorithm or multiple quality of service algorithm.

The output controller **107** then forwards the packet to the transmit queue **108**. The transmit queue **108** prepares the packet for transmission by a wide variety of ways known by those of ordinary skill in the art, e.g., adding framing bits and redundancy bits.

Fig. 3 shows an exemplary embodiment of the QoS table **104** of the present invention. Each QoS table entry includes a source/destination pair column **201**, a packet size column **202**, a timestamp of the last most recent arrival column **203**, a data period interval column **204**, a data rate column **205**, and a next arrival time column **206**.

The source/destination pair column **201** identifies a table entry's source address and destination address. Preferably, Ethernet MAC Source address and destination address pairs are used. However, any unique address pair combination, e.g., IP addresses or TCP ports may also be used in accordance with the principles of the present invention.

The packet size column **202** notes a packet size for a table entry. Preferably, the packet size column **202** notes packet size in byte units. However, other units of measure to note the size of a packet in a stream may be used in accordance with the principles of the present invention.

The timestamp column **203** notes the time of arrival of the last most recent packet arrival for a particular table entry.

The data period column **204** preferably notes the periodicity between the time of arrival of the last most recent packet arrival and the time of arrival of the current packet being processed by the data period detector **109**.

The data rate column **205** notes the data rate of a table entry detected by the data rate detector **110**. Preferably, the data rate detector **110** calculates data rate by dividing the current packet's size by the data period detected by the data rate detector **109**. However, other methods of calculating data rate are within the principles of the present invention.

The next arrival time column **206** notes the next expected arrival time of the next packet within the data stream. Preferably, the next arrival time is calculated by adding the value in the timestamp of the last most recent arrival column **203** with the value in the data period column **204**.

The QoS table **104** and columns **201-206** may be treated as a cache, so entries that are no longer in use are eventually purged after a set or default period of time. Preferably, QoS table entries are sorted according to ascending value (i.e., from soonest to latest) in the next arrival time column **206** and purged as the clock value progresses past successive next arrival times in column **206**.

Fig. 4 shows how automatic quality of service assignment may be performed at the input side of an automatic, adaptive voice/data Ethernet device **701** and **702**, in accordance with the principles of the present invention.

In particular, in step **301** automatic, adaptive voice/data Ethernet device **701** receives an incoming Ethernet packet.

Preferably, the Ethernet packet is received into the input queue **102**. The Ethernet packet is then interrogated by the input

controller **103**. The Ethernet packet may be interrogated by a wide variety of ways known by those of ordinary skill in the art.

Preferably, the Ethernet packet is interrogated for its MAC source and destination addresses. However, other information (e.g., IP addresses and/or TCP ports) from the packet may be used to identify a stream in accordance with the principles of the present invention.

In step **302**, the input controller **103** determines if the Ethernet packet is "short".

A "short" packet may be defined according to a default value or a configured value. Preferably, a "short" packet is a packet less than 120 bytes. However, other values for a "short" packet suited for voice traffic may be used in accordance with the principles of the present invention.

In step **303**, if the packet is not "short", e.g., larger than 120 bytes, then the input controller forwards the packet to output queue **105-105n** according to the priority assigned to the packet (e.g. the priority assigned by data device **706** and **707**).

In step **304**, if the packet is "short", e.g., less than 120 bytes then the input controller **103** determines whether the packet has a matching source/destination pair entry in column **201** in the QoS table **104**.

Preferably, the input controller **103** matches the packet to an entry in the QoS table **104** based upon the packet's MAC source and MAC destination addresses. However, other information (e.g., IP addresses and/or TCP ports) from the packet may be used in accordance with the principles of the present invention.

In step **308**, if no matching table entry is found, then this indicates a possible new stream and the input controller **103** makes a new table entry in the QoS table **104**.

In step **309**, the packet is forwarded to low priority output queue **105n**.

In step **305**, if the packet matches a table entry in QoS table **104** then the data period detector **109** calculates a new data period by comparing the timestamp of the most recent arrival found in column **203** with the timestamp of the current packet. In addition, the data rate detector **110** calculates a new data rate by dividing the packet size of the current packet by the new data period detected by the data period detector **109**.

In step **306**, the new data period and new data rate are compared to the values in the data period column **204** and in the data rate column **205** to determine if they are within a certain tolerance consistent with a voice stream.

The tolerance is set or defaulted to ensure that overall delay between voice devices **704** and **705** does not exceed, e.g., 10 milliseconds and that overall data rate is relatively low, e.g., less than 100 kbps. However, any tolerance value which ensures a voice quality that approximates traditional voice telephony is within the principles of the present invention.

In step **307**, if the values are within the tolerance (e.g., the packet is part of a voice stream), then the packet is forwarded to the high priority output queue **105**.

In step **309**, if the values are not within the tolerance (e.g., the packet is part of a data stream), then the packet is forwarded to low priority output queue **105n**.

Fig. 5 shows how automatic quality of service optimization may be performed at the output side of an automatic, adaptive voice/data Ethernet device, in accordance with the principles of the present invention.

In particular, as shown in Fig. 5, in step **401** the output controller receives packets from output queues **105-105n**.

In step **402**, the output controller **107** determines whether the packet is high priority (e.g., a packet that is part of a voice stream).

Determining a packet's priority may be performed in a wide variety of ways. For example, the output controller **107** may search for a matching table entry in the QoS table **104**. Preferably, the output controller **107** determines a packet's priority by noting from which output queue **105-105n** the packet was received.

In step **405**, if the packet is a high priority packet, i.e., a voice packet, then the output controller **107** forwards the packet to the transmit queue **108** for transmission to the next destination.

In step **403**, if the packet is not a high priority packet, i.e., a low priority packet, then the output controller **107** calculates the packet's completion time.

Calculating a packet completion time may performed in wide variety of ways. Preferably, the packet completion time is calculated by multiplying the packet's length and the transmission rate and adding the result to the current clock value of clock **106**.

In step **404**, the output controller **107** determines if the packet completion time of the low priority packet is greater than a next expected arrival time of a high priority packet. Preferably, the output controller **107** compares the low priority packet completion time to the soonest value in the next arrival time column **206** of the QoS table **104**.

In step **406**, if the packet completion time of the low priority packet is greater than the next arrival time of the next high priority packet, (i.e., the low priority packet may interfere with the transmission of a high priority packet in a voice stream), then the low priority packet is held for a default or set period of time.

The amount of time a low priority packet is held may be set or defaulted to a wide variety of values. Preferably, the low priority packet is held until after the soonest next arrival time in column **206** passes.

After the low priority packet has been held, the output controller **107** repeats back to step **403** and calculates the packet completion time again.

In step **405**, if the packet completion time of the low priority packet is less than the next arrival time of the next high priority packet (i.e., the low priority packet will not interfere with the transmission of a high priority packet), then the packet is forwarded to the transmit queue for transmission to the next destination.

Accordingly, the present invention provides automatic assignment of quality of service in an automatic, adaptive voice/data Ethernet device which provides the quality of service available in an explicitly-managed device, without requiring trained personnel to manually configure and maintain the device.

While the invention has been described with reference to the exemplary embodiments thereof, those skilled in the art will be able to make various modifications to the described embodiments of the invention without departing from the true spirit and scope of the invention.